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Reprinted from JOURNAL OF APPLIED PHYSIOLOGY

Vol. 11, No. 3, November, 1957

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ABSTRACT

IAMPIETRO, P. F., E. R. BUSKIRK, D. E. BASS AND B. E. WELCH. *Effect of food, climate and exercise on rectal temperature during the day.* J. Appl. Physiol. 11(3): 349–352. 1957.—A series of experiments were performed to determine the effect of climate, food intake and activity level on the diurnal pattern of rectal temperature (T_r) from 8 A.M. to 8 P.M. The results indicate that living in diverse climates has little or no effect on the diurnal pattern of T_r. Activity level, when food intake was adequate, did not alter the pattern. Fasting, with no exercise, reduced the diurnal elevation to one-half the 'normal' elevation. During fasting with exercise the rectal temperature at 8 P.M. was the same as the value at 8 A.M. (i.e. no diurnal increase was evident). Thus, the major portion of the diurnal change occurring between 8 A.M. and 8 P.M. was associated with the ingestion of food.

MANY physiological functions exhibit diurnal variations. Among these functions, the diurnal variation in body temperature has been most frequently observed. As early as 1842 Giese, quoted by Pieron (1), described variations in body temperature during the day and night. He, as well as later workers, stated that the highest daily body temperature occurred during the afternoon and the lowest values were found during the early morning hours. During the past 50 years there has been an increasing interest in the factors which alter the diurnal pattern of rectal temperature. Mühlmann (2) stated that rest, movement, food intake and sleep had no influence on the diurnal rhythm, while Brouwer (3), after an analysis of published works up to 1928, concluded that the diurnal body temperature curves were influenced by food intake, muscular activity and sleep and other unknown factors. Johansson (4) was of the opinion that only muscular activity and food intake were important factors; Kleitman (5) agrees in part with this concept, but adds sleep as well.

In the course of studies designed to describe the effects of climatic extremes and activity levels on various physiological parameters (6–8), an opportunity presented itself to obtain data on body temperatures at various times during the day. The purpose of this paper is to assess the impact of climate, food intake and activity on the pattern of rectal temperature during the hours 8:00 A.M. to 8:00 P.M.

Received for publication June 19, 1957.

PROCEDURE AND METHODS

All men used in this study were healthy young soldiers who were accustomed to the activities, feeding schedules and rations used. The data were collected during three phases as follows:

Phase I. Impact of Climate. Four men were studied while living in the subarctic at Ft. Churchill, Canada (mean daily outdoor temperature −23°F), and four men were studied while living in a temperate climate at Natick, Mass. in September (mean daily outdoor temperature 72°F). In both climates daily activity consisted in marching 9–10 miles per day cross country (4.5 miles each during morning and afternoon) and the men subsisted on Army 5-in-1 rations. They ate three meals per day at regular intervals.

Phase II. Impact of Activity. Eight men were studied at Mt. Washington, N. H. for 8 days in December (mean daily outdoor temperature 32°F). These men were studied in two situations: *a*) activity and diet as described in *phase I*, *b*) dietary regimen the same as *phase I*, but at bed rest all day.

Phase III. Impact of Food. The same eight men studied in *phase II* were used in this phase. They were studied in four situations: *a*) no food and exercise; *b*) food and exercise; *c*) no food and no exercise; *d*) food and no exercise. Food and exercise, when taken, were as described in *phase I*. On days of no food, the last meal was eaten at 5:00 P.M. of the previous day.

In all phases rectal temperatures (T_r) were measured at 8 A.M. (prebreakfast), 12 M. (prelunch), 4 P.M. (presupper) and 8 P.M. The subjects rested quietly in bed at a comfortable room temperature for 30–40 minutes before each measurement. Temperatures were measured either by calibrated rectal thermometers or by rectal catheter thermocouples and hand potentiometer.

RESULTS

Phase I. Rectal temperatures (T_r) at various hours of the day in two climates are shown in figure 1. A diurnal pattern of gradually increasing T_r during the day was found in both the temperate and the subarctic climates. In both climates T_r at 8 A.M. was significantly lower than T_r at subsequent times of measurement during the day. Comparison of T_r at

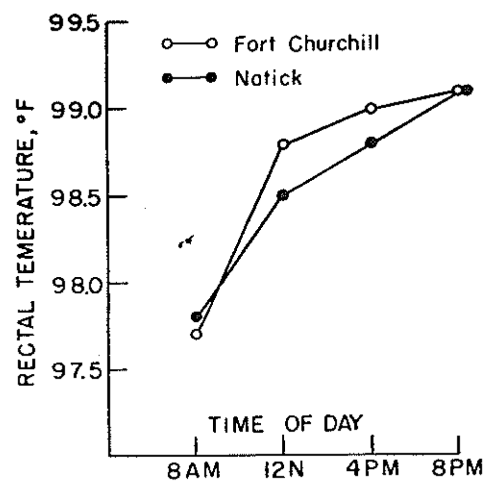

FIG. 1. Rectal temperature during the day in two climates.

TABLE 1. EFFECT OF ACTIVITY (9–10 MILE MARCH) AND NO ACTIVITY (BED REST) ON RECTAL TEMPERATURE (°F) DURING THE DAY

	Subjs.	8 A.M.	12 M.	4 P.M.	8 P.M.
Bed rest	8	98.1	98.8	99.0	99.1
March 9–10 miles	8	98.0	98.7	98.8	98.8

corresponding times of the day for each climate revealed no significant differences between climates with the exception that T_r at 12 M. was significantly higher at Ft. Churchill than at Natick. However, the mean daily T_r was not different between climates. Furthermore, the total rise during the day, 8 A.M. to 8 P.M., was essentially the same (1.4°F in the subarctic and 1.3°F in the temperate). These results confirm the findings of others (5) regarding a gradual increase in T_r during the day. In addition, the data demonstrate that the diurnal pattern is not affected by living in a cold climate.

Phase II. The data from this phase are presented in table 1. These data show no effect of activity level on the diurnal pattern. With no activity, T_r ranged from 98.1°F at 8 A.M. to 99.1°F at 8 P.M.; when the men marched 10 miles per day the range was from 98.0°F to 98.8°F. Apparently moderate activity during the day, in the presence of adequate food intake, had no effect on T_r under the conditions of these experiments.

Phase III. Figure 2 shows the effects of various combinations of food, fasting, bed rest and exercise on diurnal T_r. Figure 2*A* reveals a marked effect of fasting when exercise was performed; the upward trend normally present was reversed after 12 M. during fasting. The effect of fasting was still evident, but to a lesser extent, when no exercise was performed (fig. 2*B*). In this situation the upward trend in T_r was present, but the diurnal increase was reduced to one-half the increase when food was taken.

It should be emphasized that T_r in these experiments was measured after 30–40 minutes of bed rest. Although activity does elevate T_r, our enforced bed rest permitted re-establishment of the 'normal' diurnal value for T_r. Therefore, our curves do not reflect the transitory changes in T_r associated with acute exercise.

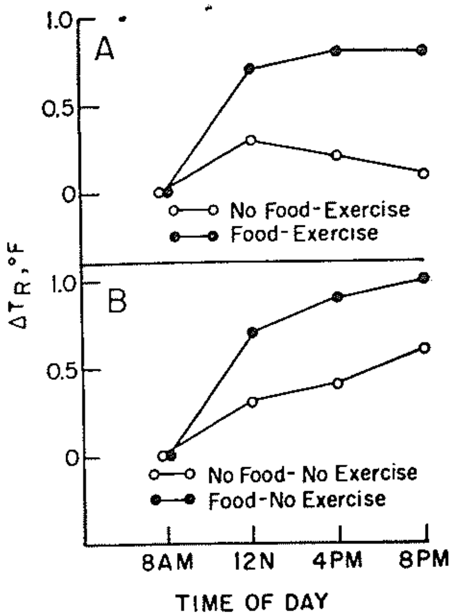

FIG. 2. Effect of food intake and exercise on rectal temperature during the day.

DISCUSSION

Although the daily cycle of T_r has been well documented (5, 9), the factors affecting this cycle are not well understood. The results of the present study indicate that the diurnal pattern of T_r during daylight hours is remarkably stable under diverse conditions, but that the pattern may be altered by certain regimens.

The data indicate that climate per se did not have a significant effect on either the absolute values for T_r during the day or on the magnitude of the increase (fig. 1). It may be questioned whether T_r measured under comfortable ambient conditions, as in the present study, are indicative of any effect of climate per se. However, other workers (10) have also shown that the diurnal variation was not affected by climate when measured at temperatures characteristic of the climate. Thus, a group of subjects living in Oxford, England showed the same diurnal pattern as a group living in Singapore. These workers, however, reported a significantly higher (0.43°F) average T_r in the Singapore group. Since we made no measurements in hot environments, no direct comparison can be made regarding the latter point. More recent work (7) reveals that nude men living at 60°F exhibited the same diurnal pattern as they did at 80°F. Furthermore, the absolute values for T_r during the day were the same as those for corresponding hours at 80°F except for those at 8 A.M.

The most intriguing finding of this study was that relating to the effects of food and exercise on T_r (*phases II* and *III*, fig. 2). When food was taken normally (3 meals per day), there was no effect of activity (march 9–10 miles per day vs. bed rest) on T_r (table 1). The fact that the magnitude of the increase in T_r during the day was the same under such greatly different levels of activity again illustrates the remarkable stability of the diurnal pattern. This stability during moderate activity indicates a complete dissipation of the extra heat produced during exercise so that the net storage (from exercise) at the end of the day was negligible. Our data agree with the conclusions of Mühlmann (2) that rest and movement have little influence on the diurnal temperature rhythm, but do not confirm the findings of others (3–5, 11). Since these authors did not standardize activity, time of feeding and type of meal for their subjects prior to actual temperature measurements, we cannot compare our findings with theirs. It is clear that fasting had a marked effect on diurnal T_r which was even more pronounced when exercise was superimposed. Although the data do not permit inferences concerning the mechanisms involved, it is interesting that the effects of fasting and exercise on T_r paralleled those of oxygen consumption in the same subjects (6). The specific dynamic action of food, which was implicated as a factor in connection with oxygen consumption, may also play a role in our findings regarding the differences between fasting and nonfasting on diurnal T_r reported here.

REFERENCES

1. PIERON, H. *Le problème physiologique du sommeil.* Paris: Masson, 1913, p. 520.

2. MÜHLMANN, M. *Arch. ges. Physiol.* 69: 613, 1898.
3. BROUWER, E. *Nederl. tijdschr. geneesk.* 72: 5319, 1928.
4. JOHANSSON, J. E. *Arch. f. Physiol.* 8: 85, 1898.
5. KLEITMAN, N. *Sleep and Wakefulness.* Chicago: Univ. Chicago Press, 1939.
6. BUSKIRK, E. R., P. F. IAMPIETRO AND B. E. WELCH. *Metabolism* 6: 144, 1957.
7. IAMPIETRO, P. F., D. E. BASS AND E. R. BUSKIRK. *J. Appl. Physiol.* 10: 398, 1957.
8. IAMPIETRO, P. F., D. E. BASS AND E. R. BUSKIRK. *Metabolism.* In press.
9. MELLETTE, H. C., B. K. HUTT, S. I. ASKOVITZ AND S. M. HORVATH. *J. Appl. Physiol.* 3: 665, 1951.
10. ADAM, J. M. AND H. M. FERRES. *J. Physiol.* 125: 21P, 1954.
11. DUBOIS, E. F. *West. J. Surg.* 59: 476, 1951.